

# BRL



CONTRACT 169

REPORT NO. 4

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UPPER ATMOSPHERE WINDS FROM  
GUN LAUNCHED VERTICAL PROBES  
(Yuma, 13-15 June 1966)

SPACE INSTRUMENTS RESEARCH, INC.

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UPPER ATMOSPHERE WINDS FROM  
GUN LAUNCHED VERTICAL PROBES  
(Yuma 13-15 June 1966)

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Prepared by:

Robert N. Fuller

Robert N. Fuller  
Research Physicist

Approved by:

Howard D. Edwards

Howard D. Edwards  
Technical Director

Space Instruments Research, Inc.  
Atlanta, Georgia

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## INTRODUCTION

For several years upper atmospheric winds over the lower West Indies have been studied by firing high altitude ballistic probes from a sixteen-inch gun. The installation of a similar 16" gun at Yuma Proving Ground, New Mexico, early in 1966 has made possible a similar study of winds in this region. These firings are being carried out by the U. S. Army Ballistics Research Laboratories, Aberdeen Proving Ground, Maryland, under the direction of Dr. Charles H. Murphy, and by the Space Research Institute of McGill University, Canada, under the direction of Dr. G. V. Bull.

Atmospheric winds are studied by releasing chemical trails from the gun-fired probes during the upper portion of their trajectories. To date, the primary chemical which has been released is trimethyl aluminum (TMA). TMA produces a chemiluminescent glow in regions of the atmosphere above 85 kilometers, thus allowing the trails to be photographed while being distorted by upper atmosphere winds. The photographs are then reduced to provide wind information by Space Instruments Research, Inc. (SIR), using computer techniques.

The purpose of this report is to summarize results of these studies for the period from June 13 through June 15, 1966. Previous results for winds over Barbados, West Indies, are covered in Technical Reports Nos. 1, 2, and 3.

## DATA ACQUISITION

The chemical trails are formed almost vertically over the gunsite (longitude 114.3°W, latitude 32.9°N) and extend from an altitude of approximately 85 kilometers through apogee. In some firings, TMA is also released on the down leg of the trajectory. To the unaided eye, the chemical release first appears as a straight white trail resembling a jet contrail. Within a minute or so, the trail is distorted into strange shapes by the upper atmospheric winds (see Figure 1) and fades from view within approximately fifteen minutes after initial release.

Space Instruments Research has established three photographic triangulation stations at Yuma and Gila Bend, Arizona, and Blythe, California. These sites are located at distances of up to 150 kilometers from the gunsite (see Figure 2).

Equipment at each site, built by SIR, consists of a camera unit containing two seven-inch focal length cameras mounted on a concrete pedestal, and an electronic control. Cameras are automatically pulsed to take exposures of 3, 6, and 12 seconds duration every 30 seconds.

Since commercial power is either unreliable or unavailable at many site locations, SIR has developed a battery operated 115-volt power supply for the control equipment. The power supply is tuning-fork controlled and provides 60 cycle power with an accuracy of 0.005% for the camera programmer so that pictures can be taken simultaneously at each site. A data block containing 24 tiny lights, mounted in each camera unit, records time, firing number, and site information in the corner of each frame of film.

During a typical night's operation, the gun is fired at one to two-hour intervals, from sunset to sunrise. Photographs are taken by all sites during the time that the trail is visible. The film is then returned to Atlanta for processing and data reduction.

## DATA REDUCTION

Several computer programs have been developed which make it possible to calculate upper atmosphere winds from measurements made directly on the photographs of the luminous trails.

Since the method used is basically three-dimensional triangulation using spherical trigonometry, it is necessary to know precisely the direction each camera was pointed during a given firing. The direction is determined by first taking accurate measurements of the locations of several star images on the film, and then computing the azimuth and elevation of the optical axis of the camera by means of a computer program. This computer program makes use of the celestial coordinates of some 6,000 stars which have been stored on magnetic tape.

Wind speeds and directions are then determined from the location of the trail in space at a succession of known times. The location is found, using either a point location program or a trail location program, or both, and depends on the physical shape of the chemical release cloud.

Point location method. If the chemical release exhibits discrete points (resulting either from turbulence or from the nature of the release mechanism) and these points can be identified on films from two or more sites, the point location program can be used to calculate the position of each point in longitude, latitude, and altitude above sea level.

These calculations are made from data taken at successive times. A wind program is then used to calculate both vertical and horizontal winds from the motion of these points as a function of time.

Trail location method. Most of the chemical releases produce a smooth trail having few, if any, identifiable points. In such cases, film coordinates of a large number of incremental points along the film image of the trail are fed into the computer from data from two or more sites. The trail location program attempts to triangulate each point from one site with many points from another site, finally choosing points from both sites whose optical paths from camera into space form the closest spatial intersection. After doing many hundreds of such calculations, the computer is able to construct coordinates for a mathematical curve in the shape of the trail in space. Then, as with the point location program, winds can be determined from the motion of the curve with time. Here, however, it must be assumed that vertical winds are essentially zero. This assumption is borne out by previous studies which have shown vertical winds in this altitude region to be of the order of a few meters per second compared to horizontal winds ranging up to 150 meters per second.

Corrections for variables such as atmospheric refraction, rotation of camera about optical axis, and camera focal length, are incorporated into the programs to maintain high accuracy. Focal length and camera rotation are, in fact, calculated from measurements of the positions of star images on the films.



## INTERPRETATION OF DATA

In the remainder of this report, horizontal wind velocities are presented in tabular form and in plots of wind speed, direction, and components.

Winds were calculated at altitude intervals of one kilometer. Points on the various plots show the actual computed result, as listed in the table preceding the plot. A curve has been fitted to each set of points to aid in detecting wind patterns and to indicate reliability of the plotted results. Each curve has been drawn with a knowledge of intermediate results leading to the wind calculations and of the consistency of the winds as calculated between each of the five or more time intervals used. In cases where point-to-point curve fitting was not thought to reflect actual variations in wind speed, direction, or components, a more appropriate smooth curve has been drawn. Otherwise, the curves are fitted directly to the data points. Results of certain portions of the trails are at times less accurate than others due to the spatial orientation of those trail segments relative to the available photographic stations. Less accurate data also can result from photographs obscured by haze and clouds and from trails of short duration.

Wind speed plot. This plot shows the speed of the wind in meters per second as a function of height in kilometers above sea level.

Wind direction plot. The wind vector is considered to point in the direction toward which the wind is moving. The direction plot shows the direction of this vector in degrees clockwise from north

as seen from above. Thus, a wind direction toward the east would be 90 degrees.

Wind components plot. While plots of wind direction and speed do completely describe the wind vector, it has been found helpful in studying wind patterns to present the north-south and east-west velocity components of the vector. In the north-south plot, north is positive; south is negative. In the east-west plot, east is positive, west negative. Components are plotted in meters per second versus height in kilometers.

The wind direction and components described above are referenced to true north. In addition, components have been calculated relative to magnetic north for comparison with other ionospheric phenomena. These components are not plotted but are listed in the tabulations preceding each set of plots.

Figure 1

Photographs of firing "McConnell"

Photographs taken 172 seconds after firing:



Yuma



Blythe



Gila Bend

These pictures were taken from three sites just as the vehicle reached apogee. Note that the winds have already distorted the trail. Numbers indicate altitude in kilometers.

Photographs taken 252 seconds after firing:



Yuma



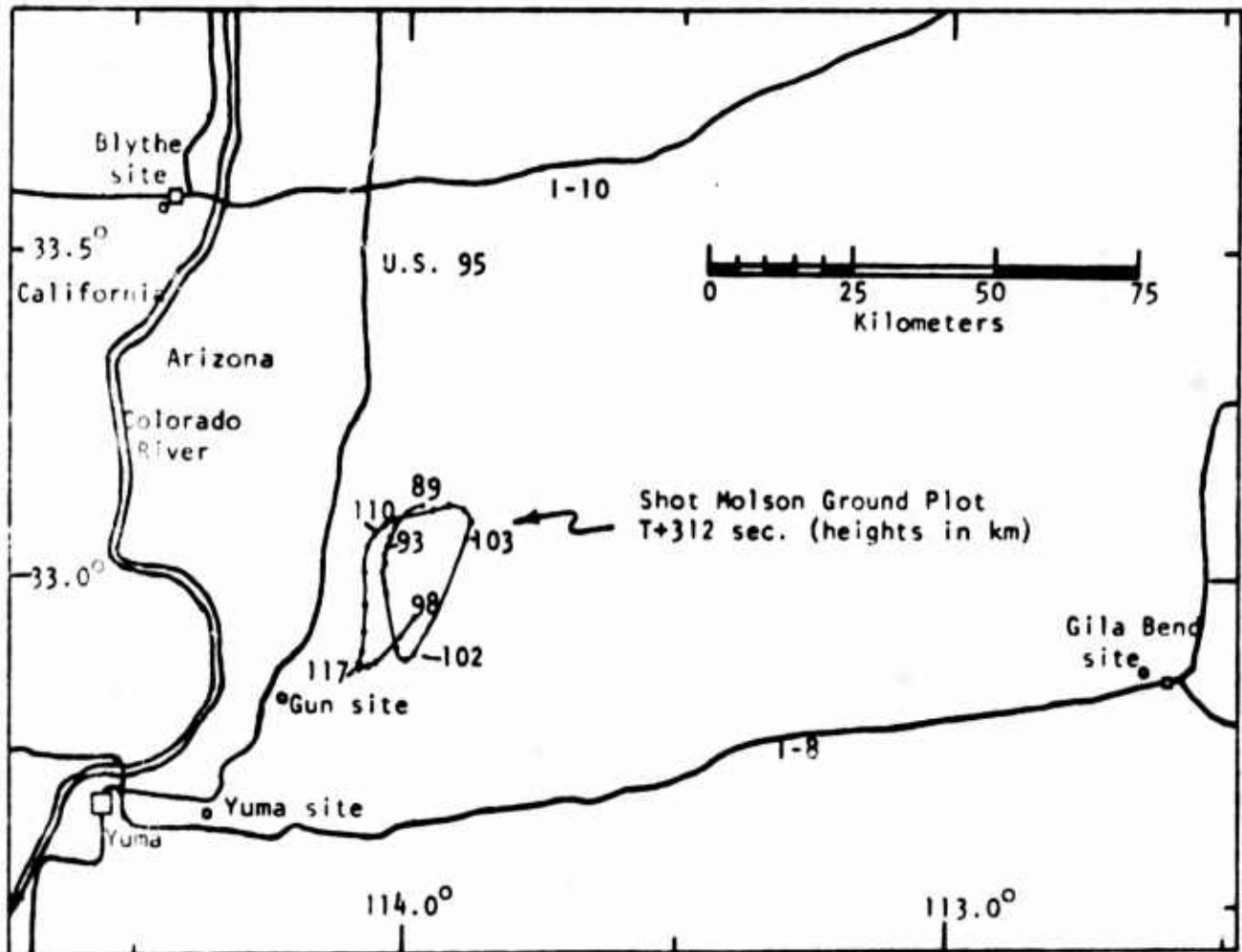
Blythe



Gila Bend

This set of pictures was taken at completion of the downtrail. The uptrail shows the continued effect of the winds, while the lower part of the downtrail is new and only slightly distorted. Stars can be seen in the background of these pictures. The positions of these stars are used to determine the exact direction each camera was aimed.

Fig. 2  
Location of SIR Photographic Stations  
HARP - Yuma



## SYNOPSIS OF RESULTS

The following comments may be helpful in interpreting the data contained in this report. Only those shots with unusual characteristics are discussed.

### DAWSON

Shot Dawson had poor data below 95km. A dotted line has been drawn on the plots to show the general trend of the winds. At 95km and above, however, the results were quite accurate.

### MCCONNELL

This was the only shot having good up and down trails. There was a distinct difference between up and down winds at many altitudes, but at other altitudes the possible errors in up and down trail results overlap. This was due to difficulty in identifying the trail because of its highly turbulent appearance. We have drawn two curves--through up and down winds. However, it is possible that at some altitudes there is no actual difference. At some altitudes there is also an indication that the uptrail winds shift at later times to agree with the downtrail at the time it was formed.

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TABLE OF TRAIL INFORMATION

<u>Trail No.</u>	<u>Name</u>	<u>Date</u>	<u>Time(MST)</u>	<u>Altitudes (km)</u>
Y1	Beatty	13 June 1966	20:25:00	94-125
Y2	Dawson	13 June 1966	22:15:01	92-121
Y3	Douglas	14 June 1966	21:46:01	91-120
Y4	McConnell	15 June 1966	01:27:00	85-115
Y5	Molson	15 June 1966	03:05:01	87-122

**TABULATIONS AND PLOTS**

**Five Trail Releases - June 13-15, 1966**

YUMA

TRAIL NO. Y1 BEATTY  
13 JUNE 1966

20-24-60 MST

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S)			
			GEOGRAPHIC		MAGNETIC	
			N-S	E-W	N-S	E-W
94.0	167.3	44.6	-43.5	9.8	-39.7	20.2
95.0	188.3	54.9	-54.3	-7.9	-54.6	5.7
96.0	192.2	47.9	-46.8	-10.1	-47.8	1.7
97.0	174.5	36.7	-36.6	3.5	-34.6	12.4
98.0	89.2	34.8	0.5	34.8	9.1	33.6
99.0	92.5	46.5	-2.1	46.5	9.4	45.6
100.0	102.4	65.7	-14.1	64.2	2.1	65.7
101.0	106.3	57.4	-16.1	55.1	-2.0	57.4
102.0	102.4	71.7	-15.4	70.0	2.3	71.6
103.0	122.8	77.6	-42.0	65.3	-24.6	73.6
104.0	126.4	80.9	-48.0	65.1	-30.5	74.9
105.0	113.9	72.3	-29.2	66.1	-12.0	71.3
106.0	104.3	76.0	-18.7	73.6	0.0	75.9
107.0	107.9	85.2	-26.2	81.0	-5.5	85.0
108.0	112.1	88.0	-33.1	81.5	-12.0	87.1
109.0	118.2	71.7	-33.9	63.2	-17.3	69.6
110.0	128.3	44.2	-27.4	34.7	-18.0	40.4
111.0	159.4	12.9	-12.1	4.5	-10.6	7.3
112.0	234.5	11.5	-6.7	-9.4	-8.8	-7.5
113.0	272.3	31.9	1.3	-31.8	-6.6	-31.1
114.0	276.6	39.5	4.5	-39.2	-5.3	-39.1
115.0	273.3	46.7	2.7	-46.6	-8.9	-45.6
116.0	257.8	45.4	-9.6	-44.4	-20.2	-40.7
117.0	242.7	47.2	-21.7	-41.9	-31.3	-35.3
118.0	226.9	51.0	-34.9	-37.2	-43.0	-27.5
119.0	220.4	55.8	-42.5	-36.1	-50.1	-24.5
120.0	212.4	61.5	-51.9	-32.9	-58.4	-19.1
121.0	207.7	73.0	-64.6	-33.9	-71.0	-17.0
122.0	203.2	72.4	-66.6	-28.5	-71.6	-11.2
123.0	199.3	75.2	-71.0	-24.8	-74.9	-6.6
124.0	196.5	75.8	-72.7	-21.5	-75.8	-2.9
125.0	193.6	72.7	-70.7	-17.1	-72.7	0.8

# WIND COMPONENTS

TRAIL NO. Y1 BEATTY

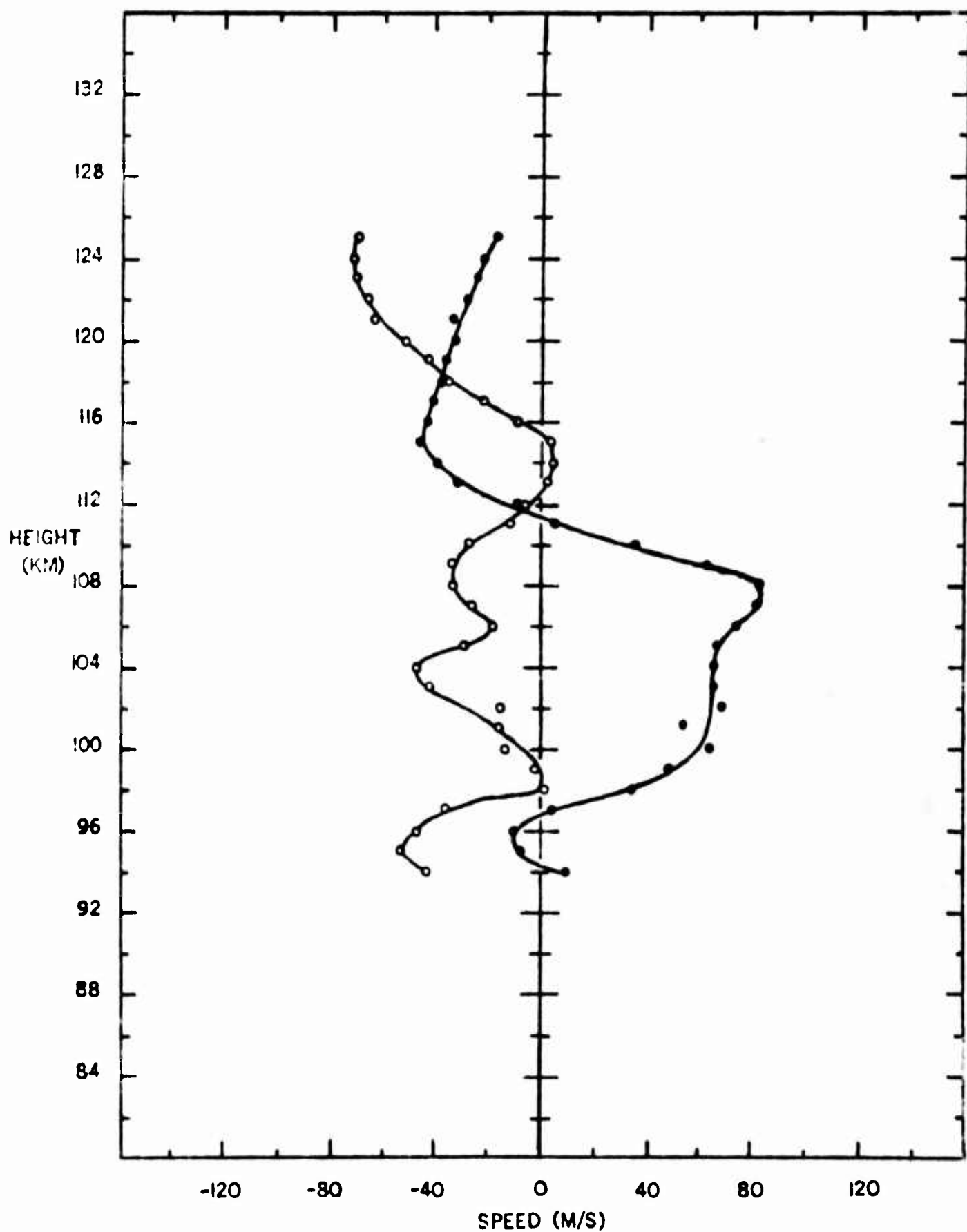
UP DOWN

13 JUNE 1966 20:25:00

○ ▲ NORTH-SOUTH

HARP. YUMA

● ▲ EAST-WEST



WIND SPEED

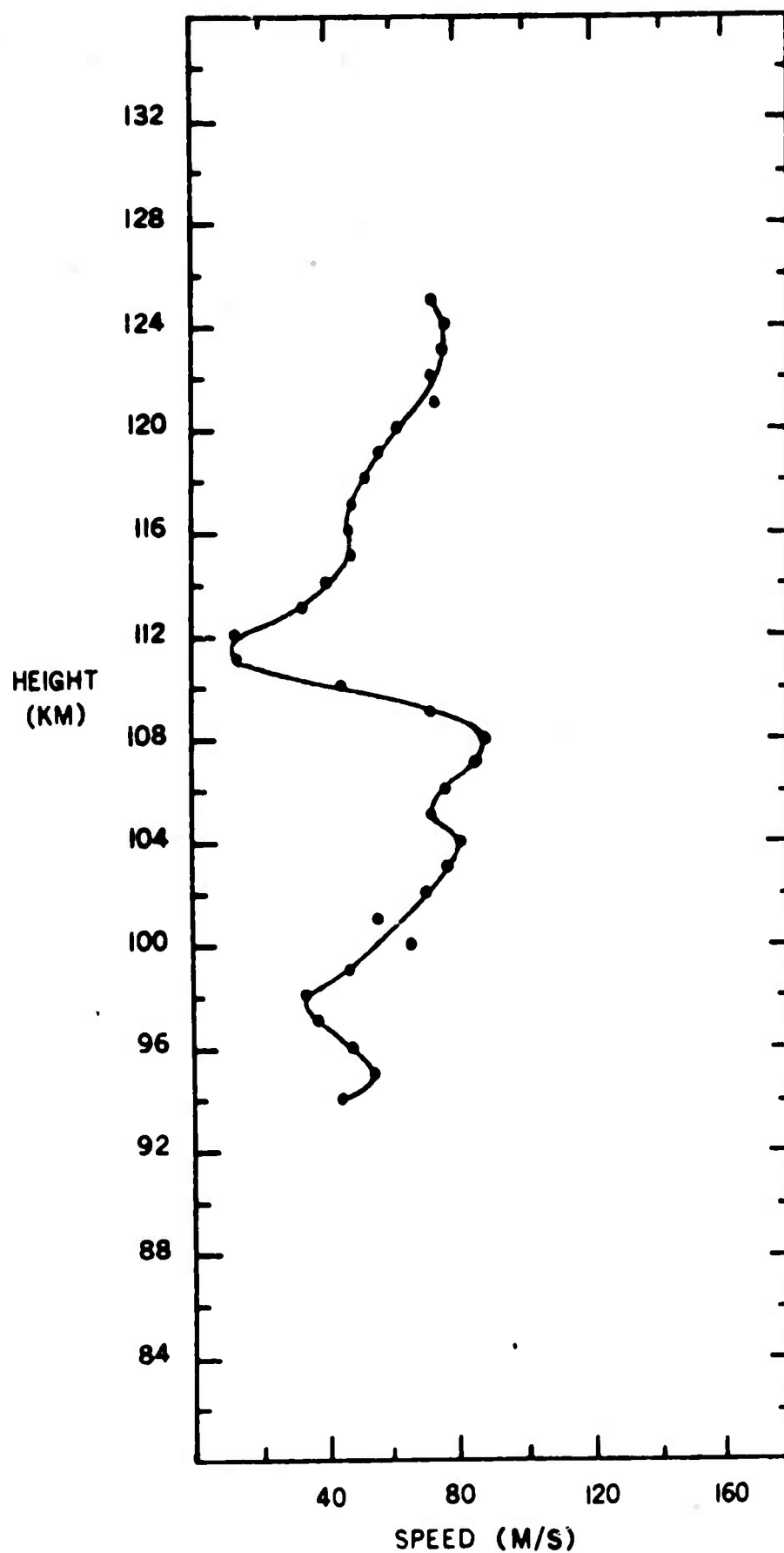
TRAIL NO. Y1 BEATTY

● UP TRAIL

13 JUNE 1966 20:25:00

▲ DOWN TRAIL

H.A.R.P. YUMA



WIND DIRECTION

TRAIL NO. Y1

BEATTY

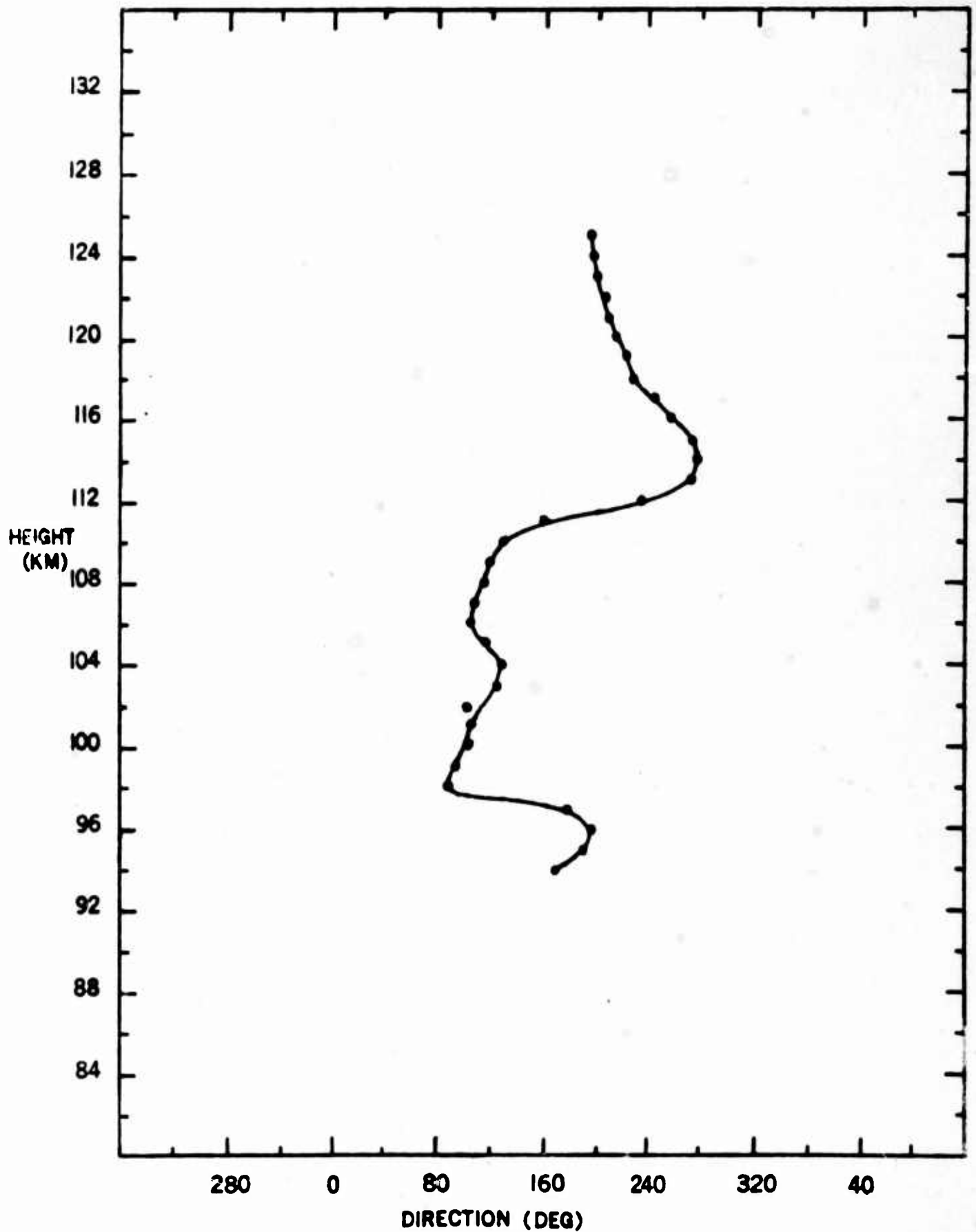
● UP TRAIL

13 JUNE 1966

20:25:00

▲ DOWN TRAIL

HARP. YUMA



YUMA

TRAIL NO. Y2 DAWSON  
13 JUNE 1966

22-15-01 MST

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S)			
			GEOGRAPHIC		MAGNETIC	
			N-S	E-W	N-S	E-W
92.0	163.2	45.5	-43.5	13.1	-38.9	23.4
93.0	167.3	23.1	-22.6	5.1	-20.6	10.5
94.0	164.5	50.1	-48.2	13.4	-43.4	24.9
95.0	52.8	13.7	8.3	10.9	10.7	8.5
96.0	83.7	45.6	5.0	45.3	16.0	42.7
97.0	80.0	60.2	10.5	59.3	24.8	54.9
98.0	84.1	82.1	8.5	81.7	28.3	77.1
99.0	93.8	95.3	-6.4	95.1	17.2	93.7
100.0	103.6	110.7	-26.1	107.6	1.2	110.7
101.0	106.6	117.9	-33.6	113.0	-4.8	117.8
102.0	109.4	116.2	-38.7	109.6	-10.5	115.8
103.0	115.1	113.6	-48.1	102.9	-21.3	111.6
104.0	122.1	111.9	-59.4	94.8	-34.2	106.5
105.0	129.8	104.7	-67.0	80.4	-45.1	94.4
106.0	141.2	100.5	-78.3	63.0	-60.4	80.3
107.0	164.4	98.2	-94.6	26.4	-85.2	48.9
108.0	179.3	102.3	-102.2	1.3	-98.7	26.4
109.0	202.5	104.6	-96.6	-40.0	-103.5	-15.0
110.0	213.0	103.2	-86.5	-56.2	-97.7	-33.2
111.0	215.7	103.6	-84.2	-60.4	-96.5	-37.8
112.0	218.6	92.3	-72.2	-57.6	-84.2	-38.1
113.0	226.4	75.7	-52.2	-54.8	-64.1	-40.3
114.0	234.5	70.8	-41.1	-57.6	-54.0	-45.7
115.0	243.5	67.2	-30.0	-60.1	-43.9	-50.9
116.0	247.1	67.0	-26.1	-61.7	-40.5	-53.4
117.0	247.9	66.9	-25.1	-62.0	-39.6	-53.9
118.0	244.2	67.1	-29.2	-60.4	-43.2	-51.4
119.0	238.8	67.7	-35.1	-57.9	-48.3	-47.5
120.0	233.8	71.2	-42.0	-57.4	-54.8	-45.3
121.0	229.9	77.7	-50.1	-59.5	-63.2	-45.3

## WIND COMPONENTS

TRAIL NO. Y2

DAWSON

UP DOWN

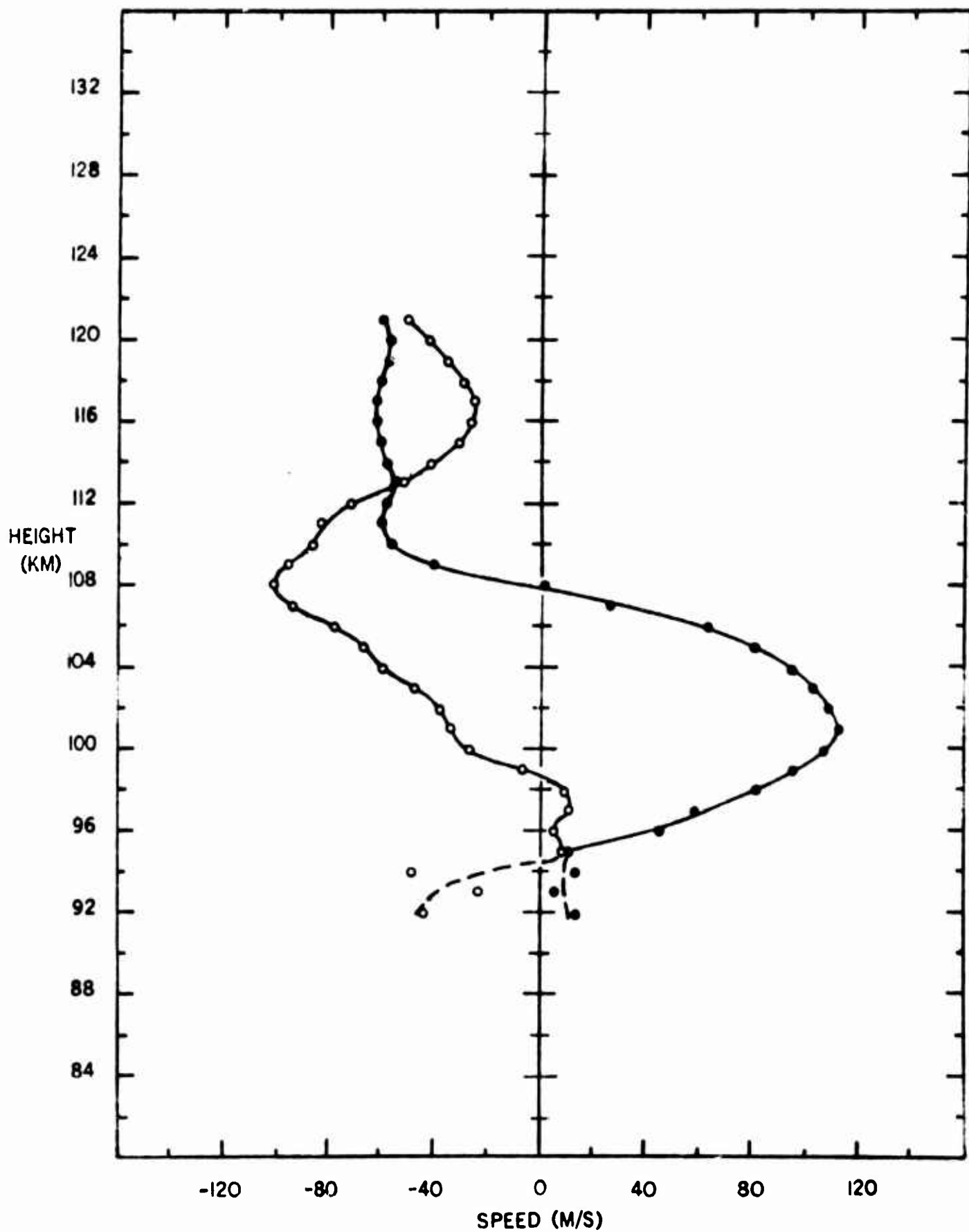
13 JUNE 1966

22:15:01

○ ▲ NORTH-SOUTH

HARP. YUMA

● ▲ EAST-WEST





WIND SPEED

TRAIL NO. Y2

DAWSON

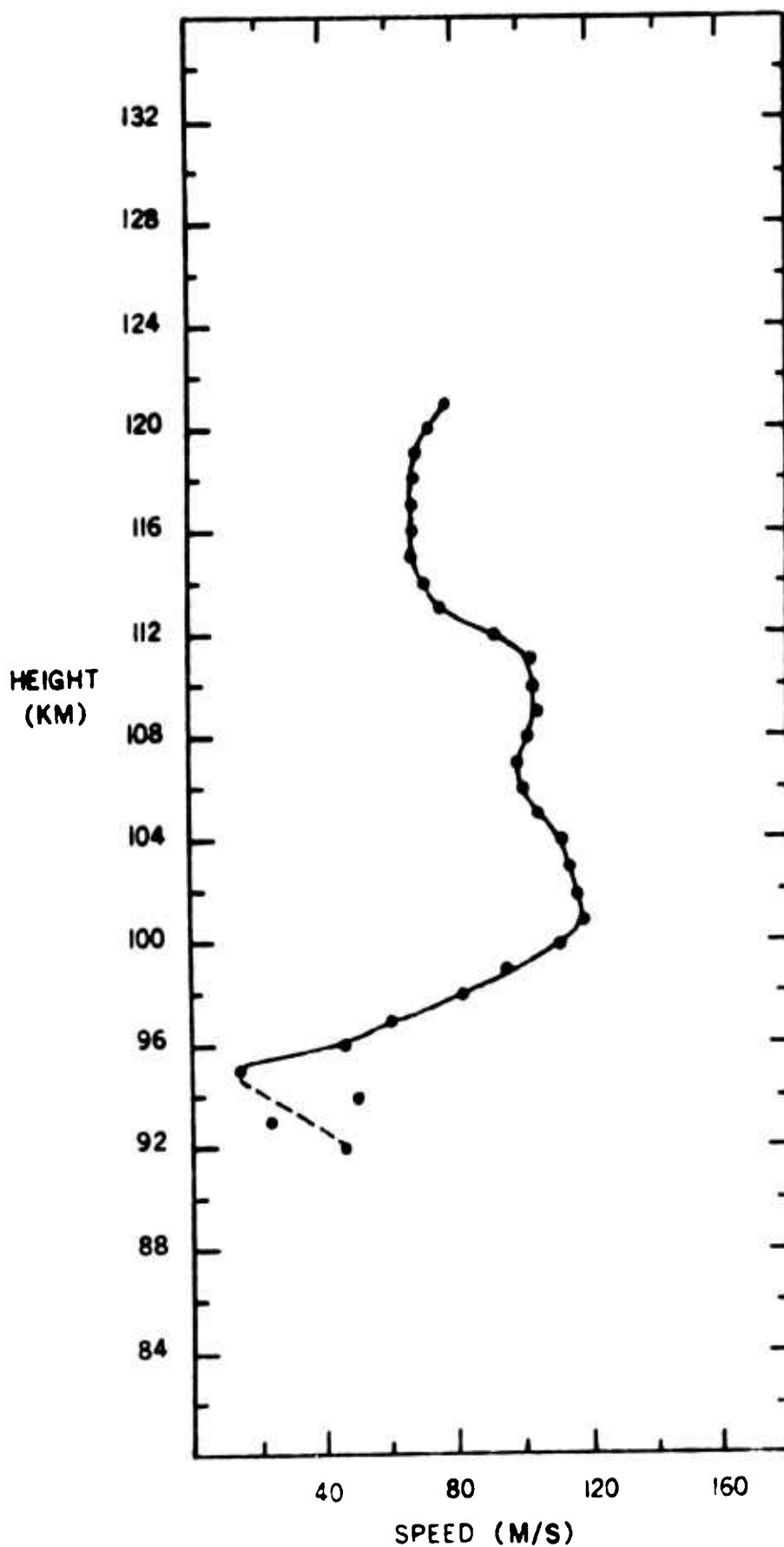
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13 JUNE 1966

22:15:01

▲ DOWN TRAIL

H.A.R.P. YUMA



WIND DIRECTION

TRAIL NO. Y2

DAWSON

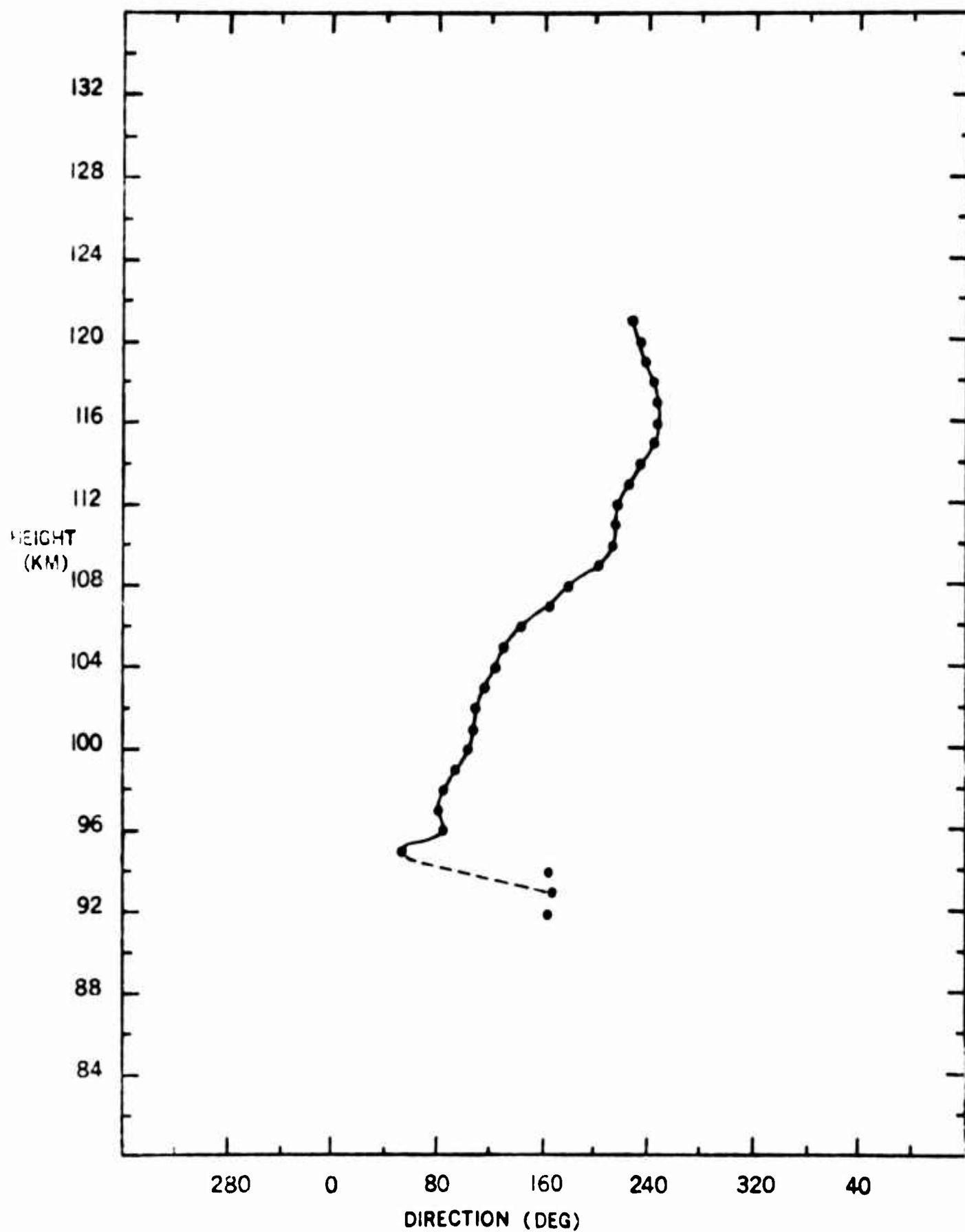
● UP TRAIL

13 JUNE 1966

22:15:01

▲ DOWN TRAIL

H.A.R.P. YUMA



YUMA

TRAIL NO. Y3 DOUGLAS

14 JUNE 1966

21-46-01 MST

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S)			
			GEOGRAPHIC		MAGNETIC	
			N-S	E-W	N-S	E-W
91.0	100.8	34.4	-6.5	33.8	2.0	34.4
92.0	104.5	35.3	-8.8	34.2	-0.1	35.3
93.0	64.3	54.9	23.8	49.5	35.3	42.1
94.0	62.6	61.3	28.2	54.4	40.7	45.8
95.0	62.0	66.1	31.0	58.4	44.4	49.0
96.0	70.3	67.8	22.9	63.8	37.9	56.2
97.0	94.7	81.6	-6.7	81.4	13.5	80.5
98.0	97.9	85.1	-11.8	84.3	9.3	84.6
99.0	99.6	82.7	-19.8	81.6	6.7	82.5
100.0	101.4	82.2	-16.2	80.6	4.1	82.1
101.0	104.5	80.5	-20.2	78.0	-0.4	80.6
102.0	115.7	75.0	-32.6	67.5	-15.0	73.4
103.0	122.0	69.8	-37.0	59.2	-21.3	66.5
104.0	130.4	46.9	-30.4	35.7	-20.7	42.1
105.0	253.5	75.0	-21.4	-71.8	-38.4	-64.3
106.0	271.2	77.4	1.6	-77.4	-17.5	-75.4
107.0	277.2	80.4	10.1	-79.8	-9.9	-79.8
108.0	289.3	74.7	24.6	-70.5	6.5	-74.4
109.0	285.4	69.3	18.4	-66.8	1.4	-69.3
110.0	280.0	68.8	11.9	-67.8	-5.2	-68.6
111.0	280.8	69.5	13.0	-68.3	-4.2	-69.4
112.0	263.1	71.1	-8.6	-70.6	-25.7	-66.3
113.0	261.0	73.2	-11.5	-72.3	-28.9	-67.2
114.0	245.0	83.3	-35.2	-75.5	-52.7	-64.5
115.0	238.3	89.8	-47.1	-76.4	-64.5	-62.5
116.0	234.1	95.3	-55.9	-77.1	-73.2	-61.0
117.0	232.5	99.5	-60.5	-79.0	-78.1	-61.7
118.0	229.7	104.8	-67.8	-79.9	-85.4	-60.8
119.0	225.8	67.9	-47.4	-48.7	-57.9	-35.5
120.0	223.3	60.5	-44.0	-41.5	-52.9	-29.4

# WIND COMPONENTS

TRAIL NO. Y3

DOUGLAS

UP DOWN

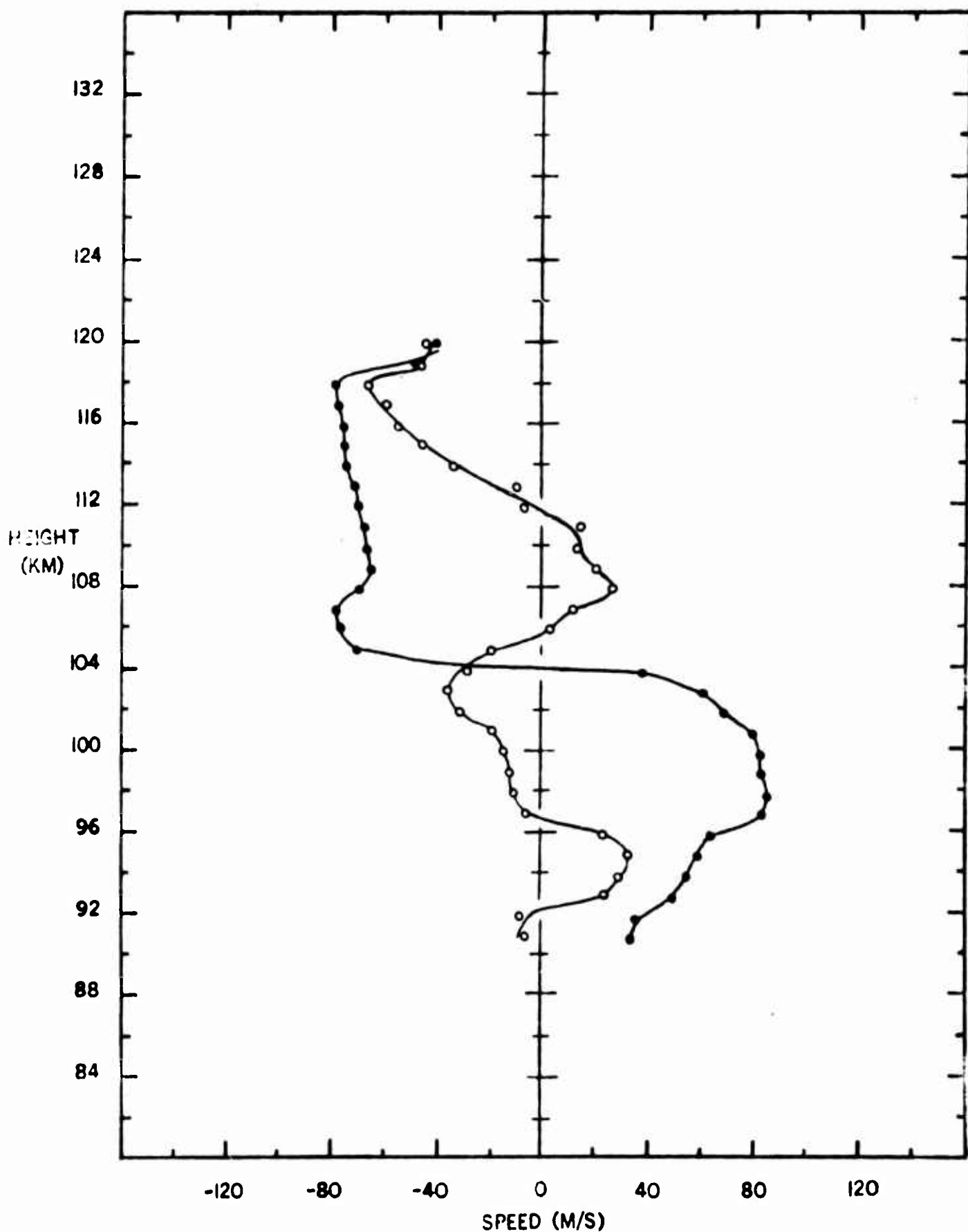
14 JUNE 1966

21:46:01

○ ▲ NORTH-SOUTH

HARP. YUMA

● ▲ EAST-WEST



WIND SPEED

TRAIL NO. Y3

DOUGLAS

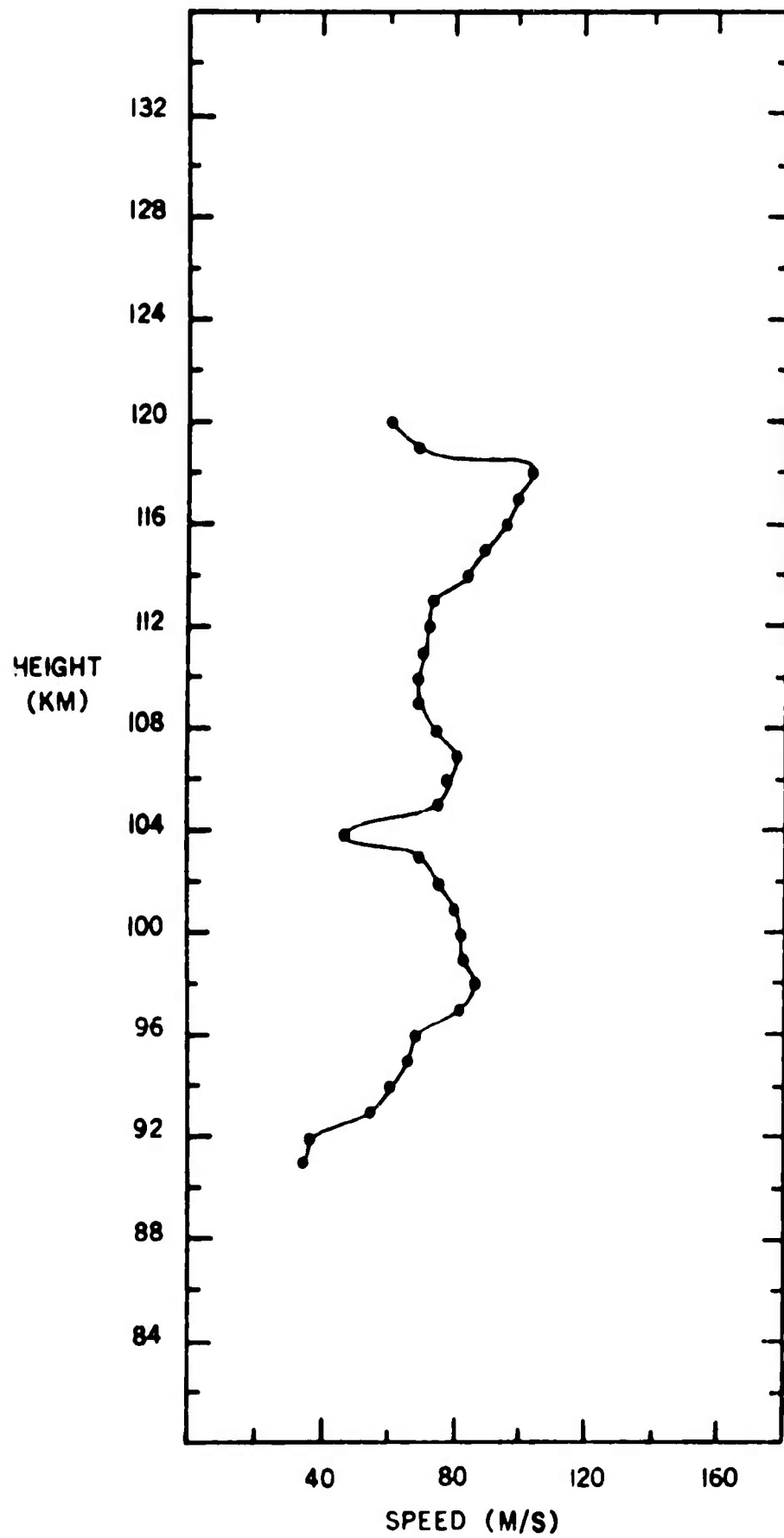
● UP TRAIL

14 JUNE 1966

21:46:01

▲ DOWN TRAIL

H.A.R.P. YUMA



WIND DIRECTION

TRAIL NO. Y3

DOUGLAS

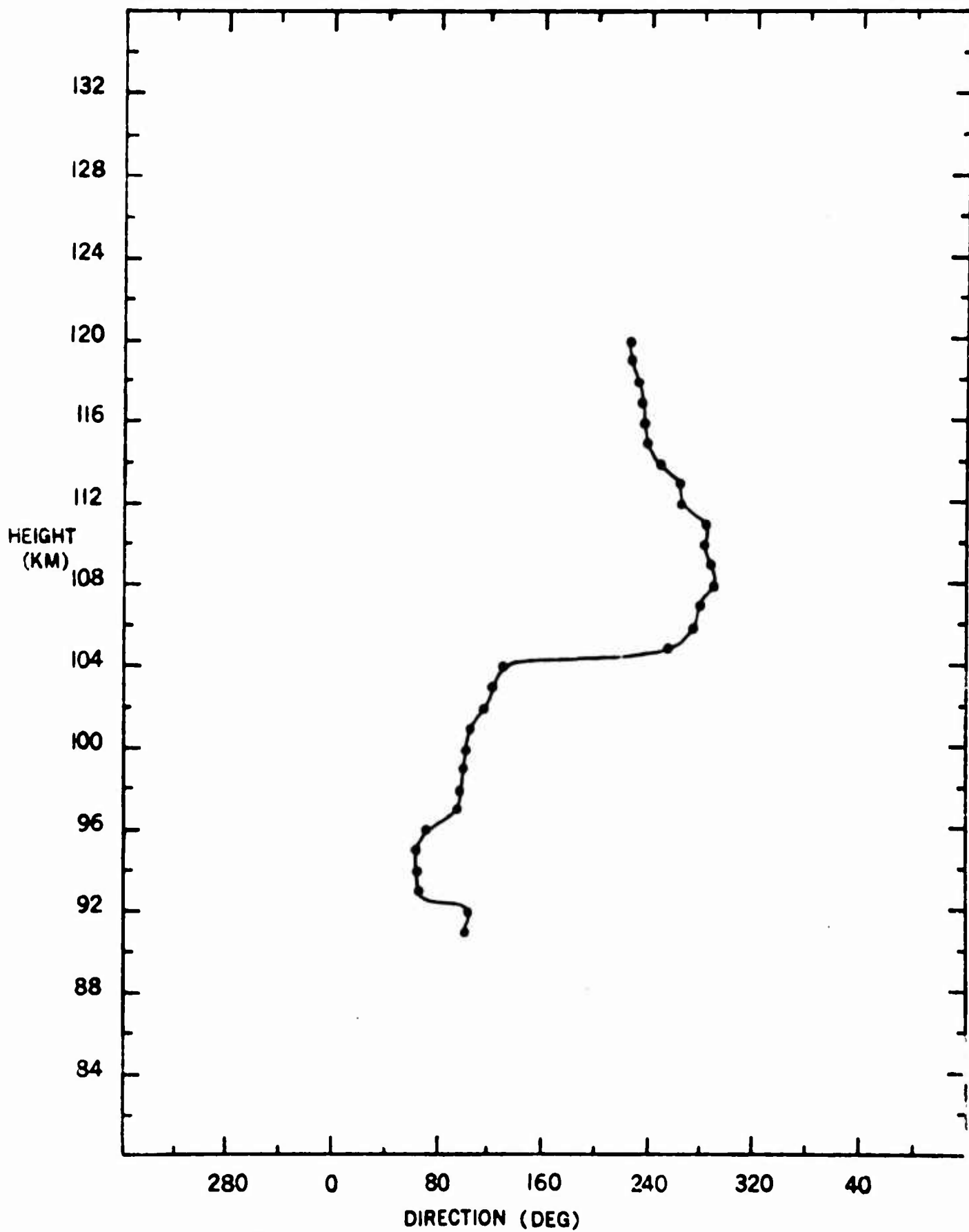
● UP TRAIL

14 JUNE 1966

21:46:01

▲ DOWN TRAIL

H.A.R.P. YUMA



YUMA  
UP TRAIL

TRAIL NO. Y4 McCONNELL  
15 JUNE 1966

01-27 00 MST

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S)			
			GEOGRAPHIC		MAGNETIC	
			N-S	E-W	N-S	E-W
85.0	242.4	32.9	-15.2	-29.1	-21.9	-24.5
86.0	267.0	42.5	-2.2	-42.4	-12.6	-40.6
87.0	281.1	47.5	9.1	-46.6	-2.7	-47.4
88.0	314.0	36.9	25.6	-26.6	18.3	-32.1
89.0	9.6	39.9	39.3	6.6	39.7	-3.3
90.0	24.8	58.0	52.6	24.3	57.0	10.6
91.0	43.5	53.1	38.6	36.6	46.4	26.0
92.0	61.7	53.9	25.5	47.5	36.4	39.8
93.0	72.4	59.5	18.0	56.7	31.4	50.5
94.0	77.5	62.7	13.5	61.2	28.1	56.0
95.0	80.1	62.9	10.8	61.9	25.7	57.3
96.0	80.4	57.9	9.6	57.1	23.4	53.0
97.0	75.0	48.0	12.4	46.3	23.4	41.8
98.0	75.5	49.6	12.4	48.0	23.8	43.5
99.0	78.7	53.9	10.6	52.8	23.3	48.6
100.0	82.9	57.0	7.1	56.5	20.8	53.0
101.0	93.0	50.2	-2.6	50.1	9.8	49.2
102.0	110.5	43.0	-15.1	40.2	-4.7	42.7
103.0	136.2	48.8	-35.3	33.8	-25.9	41.4
104.0	176.5	57.7	-57.6	3.6	-54.9	17.7
105.0	221.8	53.1	-39.6	-35.4	-47.1	-24.6
106.0	245.5	52.9	-21.9	-48.1	-33.1	-41.2
107.0	265.5	66.3	-5.2	-66.1	-21.3	-62.8
108.0	275.1	79.8	7.1	-79.5	-12.7	-78.8
109.0	272.3	87.4	3.5	-87.3	-18.1	-85.5
110.0	267.1	78.6	-4.0	-78.5	-23.2	-75.1
111.0	263.7	62.5	-6.8	-62.1	-21.9	-58.5
112.0	266.5	55.5	-3.4	-55.4	-16.9	-52.9
113.0	276.1	28.6	3.0	-28.4	-4.1	-28.3
114.0	291.3	25.5	9.3	-23.8	3.2	-25.4

YUMA  
DOWN TRAIL

TRAIL NO. Y4 M CONNELL  
15 JUNE 1966

01-27 00 MST

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S)			
			GEOGRAPHIC		MAGNETIC	
			N-S	E-W	N-S	E-W
97.0	76.4	52.2	12.3	50.8	24.4	46.2
98.0	79.0	57.5	11.0	56.5	24.6	52.1
99.0	87.1	60.4	3.1	60.3	17.8	57.7
100.0	95.3	53.6	-4.9	53.4	8.4	53.0
101.0	102.7	50.5	-11.1	49.2	1.4	50.4
102.0	128.8	49.8	-31.2	38.8	-20.7	45.3
103.0	139.9	52.2	-39.9	33.7	-30.4	42.5
104.0	161.6	52.4	-49.7	16.6	-44.1	28.3
105.0	221.7	38.6	-28.8	-25.7	-34.2	-17.8
106.0	251.6	43.5	-13.7	-41.2	-23.4	-36.6
107.0	268.6	69.4	-1.8	-69.3	-18.8	-66.7
108.0	267.7	94.9	-3.8	-94.8	-27.0	-90.9
109.0	262.8	83.1	-10.4	-82.4	-30.4	-77.3
110.0	259.5	69.1	-12.5	-67.9	-28.8	-62.7
111.0	257.0	50.9	-11.5	-49.6	-23.4	-45.2
112.0	256.7	37.7	-8.7	-36.7	-17.5	-33.4
113.0	260.1	25.8	-4.4	-25.4	-10.5	-23.5
114.0	325.8	14.6	12.0	-8.2	9.6	-10.9
115.0	6.8	24.5	24.4	2.9	24.4	-3.2



## WIND COMPONENTS

TRAIL NO. Y4

McCONNELL

UP DOWN

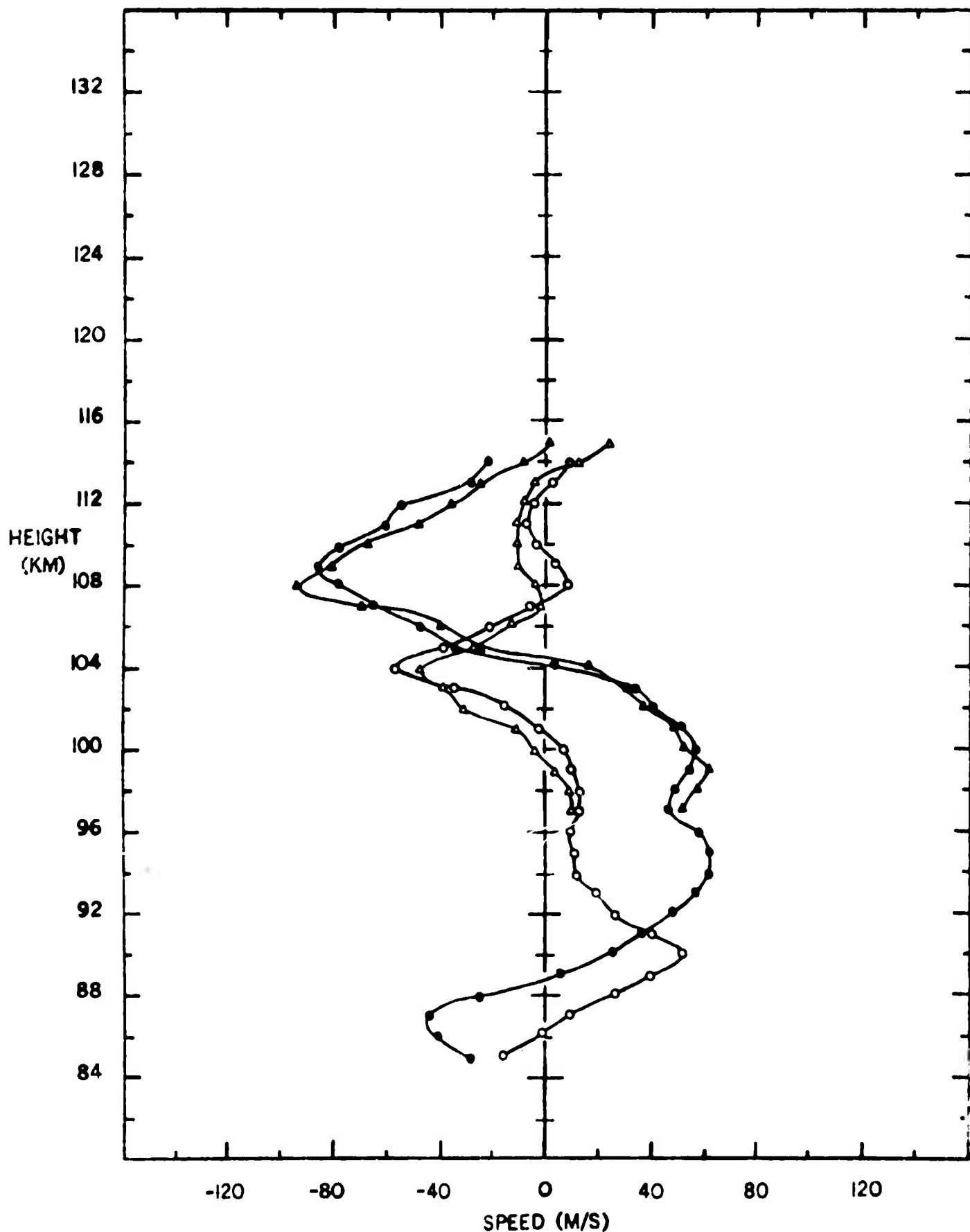
15 JUNE 1966

01:27:00

○ ▲ NORTH-SOUTH

HARP. YUMA

● ▲ EAST-WEST



WIND SPEED

TRAIL NO. Y4

McCONNELL

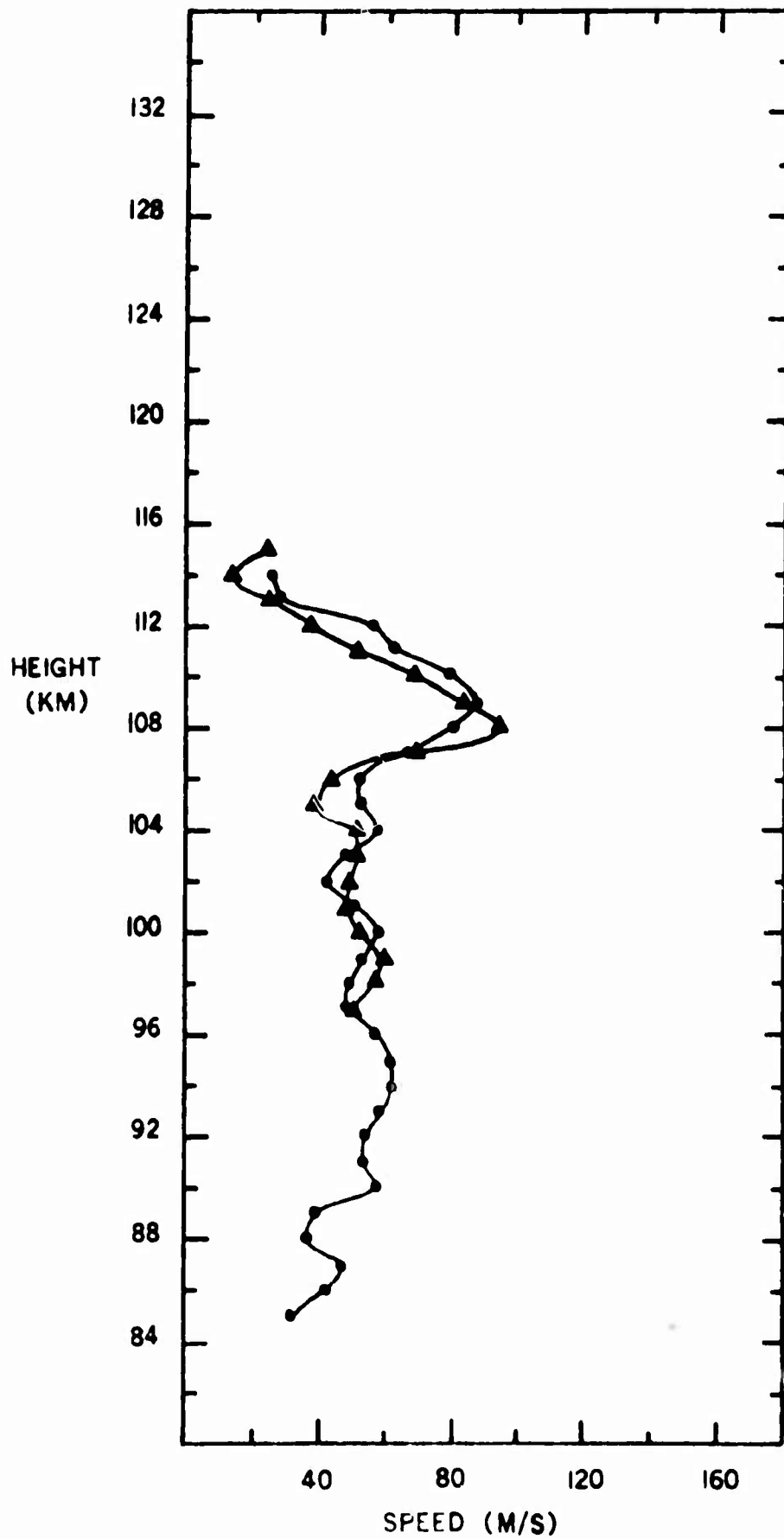
● UP TRAIL

15 JUNE 1966

01:27:00

▲ DOWN TRAIL

H.A.R.P. YUMA



WIND DIRECTION

TRAIL NO. Y4

McCONNELL

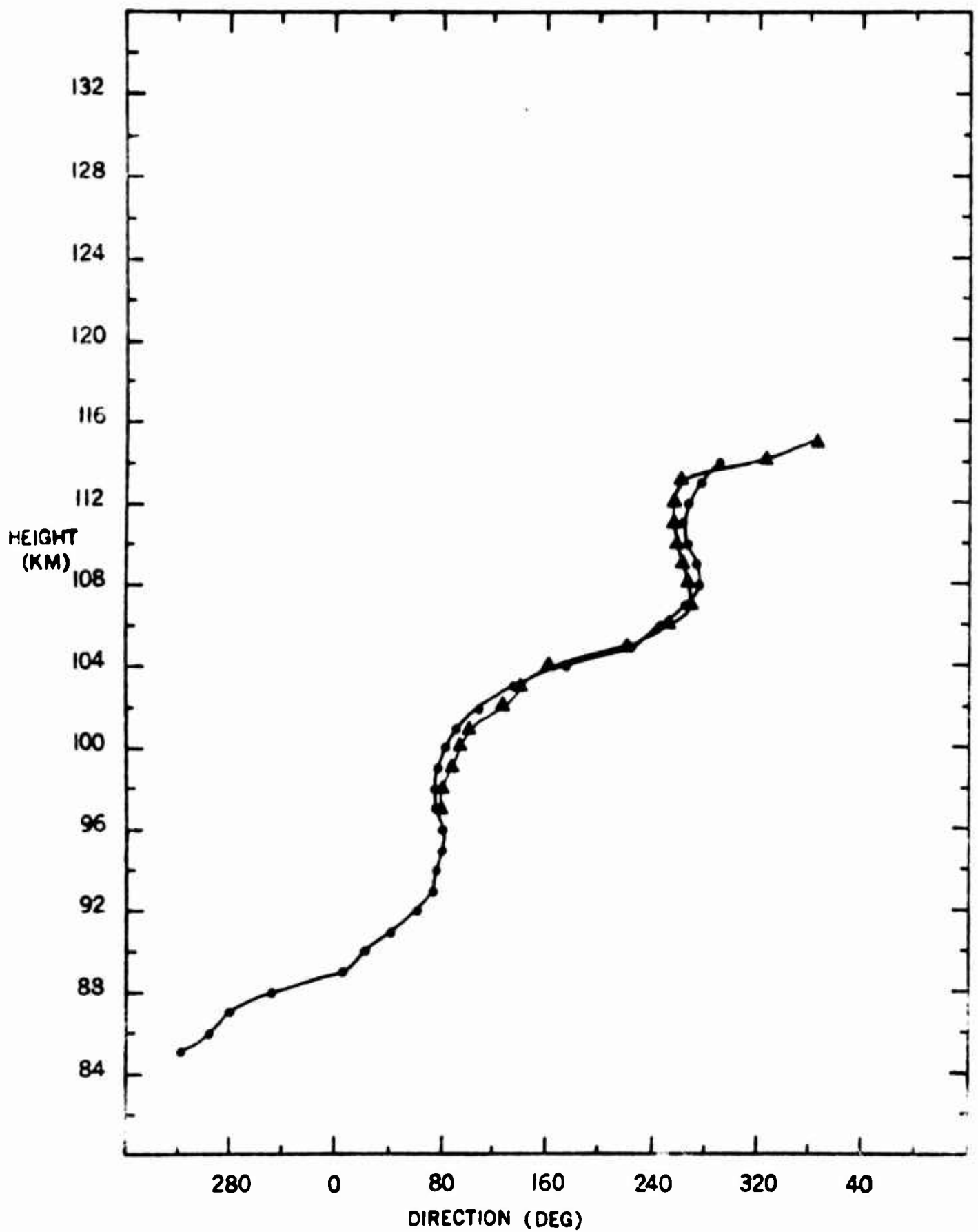
● UP TRAIL

15 JUNE 1966

01:27:00

▲ DOWN TRAIL

H.A.R.P. YUMA



YUMA

TRAIL NO. Y5 MOLSON  
15 JUNE 1966

03-05-01 MST

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S)			
			GEOGRAPHIC		MAGNETIC	
			N-S	E-W	N-S	E-W
87.0	343.5	50.4	48.3	-14.3	43.3	-25.7
88.0	344.7	50.6	48.8	-13.3	44.0	-24.9
89.0	337.6	59.3	54.8	-22.6	47.6	-35.4
90.0	331.8	58.8	51.8	-27.7	43.4	-39.6
91.0	22.2	46.8	43.3	17.7	46.3	6.5
92.0	62.3	66.7	31.0	59.0	44.6	49.6
93.0	65.9	67.8	27.6	61.9	42.0	53.2
94.0	73.8	78.7	21.9	75.6	39.8	67.9
95.0	76.3	83.1	19.6	80.7	38.9	73.4
96.0	77.9	83.2	17.5	81.4	37.0	74.6
97.0	92.5	73.1	-3.2	73.0	14.9	71.5
98.0	112.6	71.4	-27.4	66.0	-10.3	70.7
99.0	136.1	84.3	-60.7	58.5	-44.4	71.6
100.0	161.4	78.0	-73.9	24.9	-65.5	42.3
101.0	180.5	71.2	-71.2	-0.7	-69.2	16.8
102.0	190.3	60.3	-59.3	-10.8	-60.1	4.1
103.0	298.3	59.0	28.0	-51.9	14.4	-57.2
104.0	304.4	69.6	39.3	-57.4	24.0	-65.3
105.0	309.6	68.3	43.5	-52.6	29.2	-61.7
106.0	314.9	60.5	42.7	-42.8	30.9	-52.0
107.0	316.3	58.3	42.2	-40.2	31.0	-49.4
108.0	347.5	44.0	42.9	-9.5	39.2	-19.8
109.0	354.3	43.9	43.7	-4.3	41.3	-14.9
110.0	359.5	40.3	40.3	-0.3	39.0	-10.2
111.0	0.8	37.8	37.8	0.5	36.8	-8.8
112.0	10.2	23.5	23.1	4.1	23.4	-1.7
113.0	118.9	11.6	-5.6	10.2	-2.9	11.3
114.0	156.9	39.5	-36.4	15.5	-31.5	24.0
115.0	164.5	66.3	-63.9	17.7	-57.6	32.9
116.0	166.6	82.0	-79.8	19.1	-72.6	38.2
117.0	170.0	83.7	-82.4	14.5	-76.3	34.3
118.0	171.1	85.4	-84.3	13.2	-78.5	33.5
119.0	178.7	76.6	-76.6	1.8	-73.8	20.6
120.0	194.8	70.3	-68.0	-18.0	-70.3	-0.7
121.0	215.4	72.3	-58.9	-41.8	-67.4	-26.0
122.0	223.0	86.1	-63.0	-58.7	-75.5	-41.4

# WIND COMPONENTS

TRAIL NO. Y5

MOLSON

UP DOWN

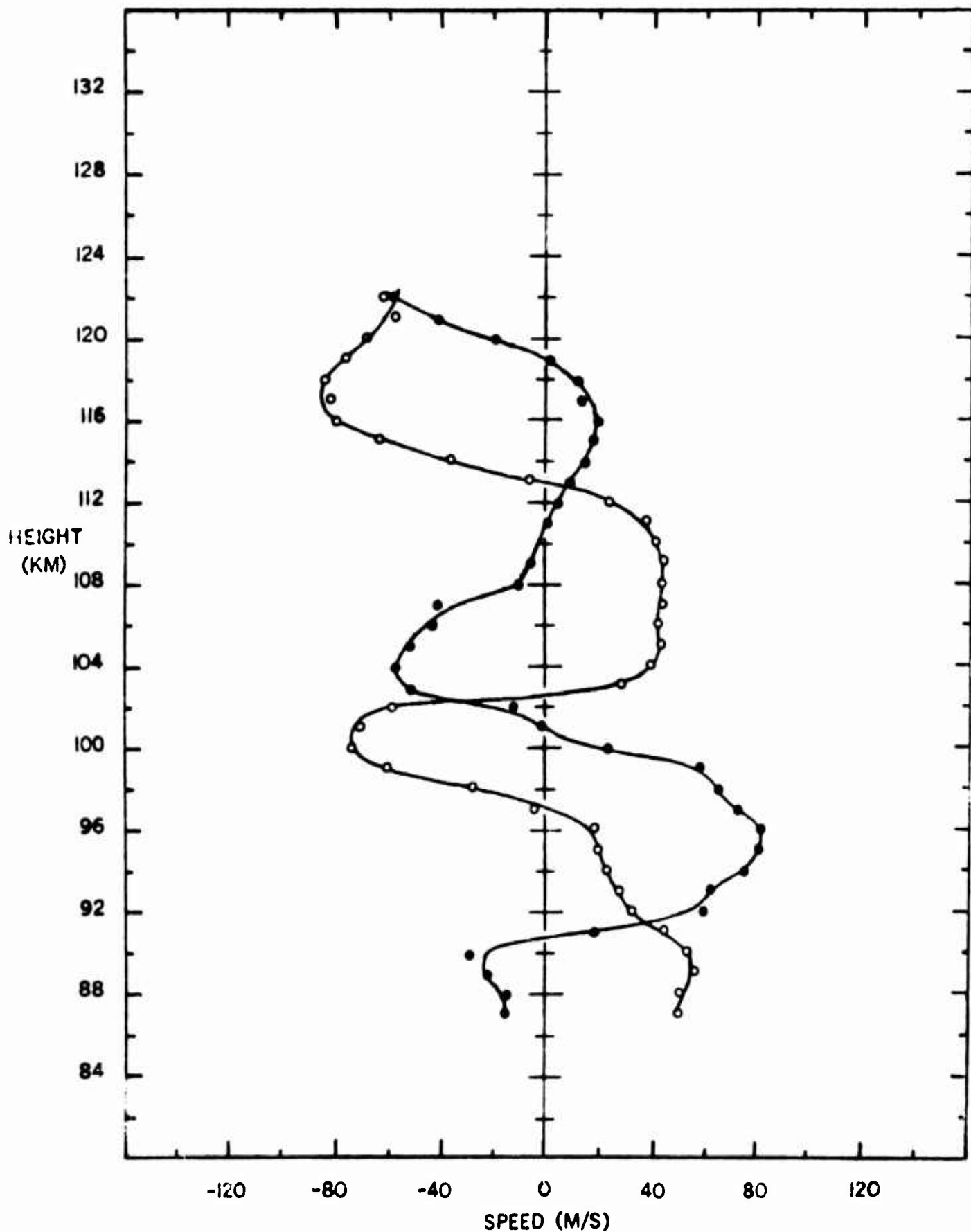
15 JUNE 1966

03:05:01

○ ▲ NORTH-SOUTH

HARP. YUMA

● ▲ EAST-WEST



WIND SPEED

TRAIL NO. Y5

MOLSON

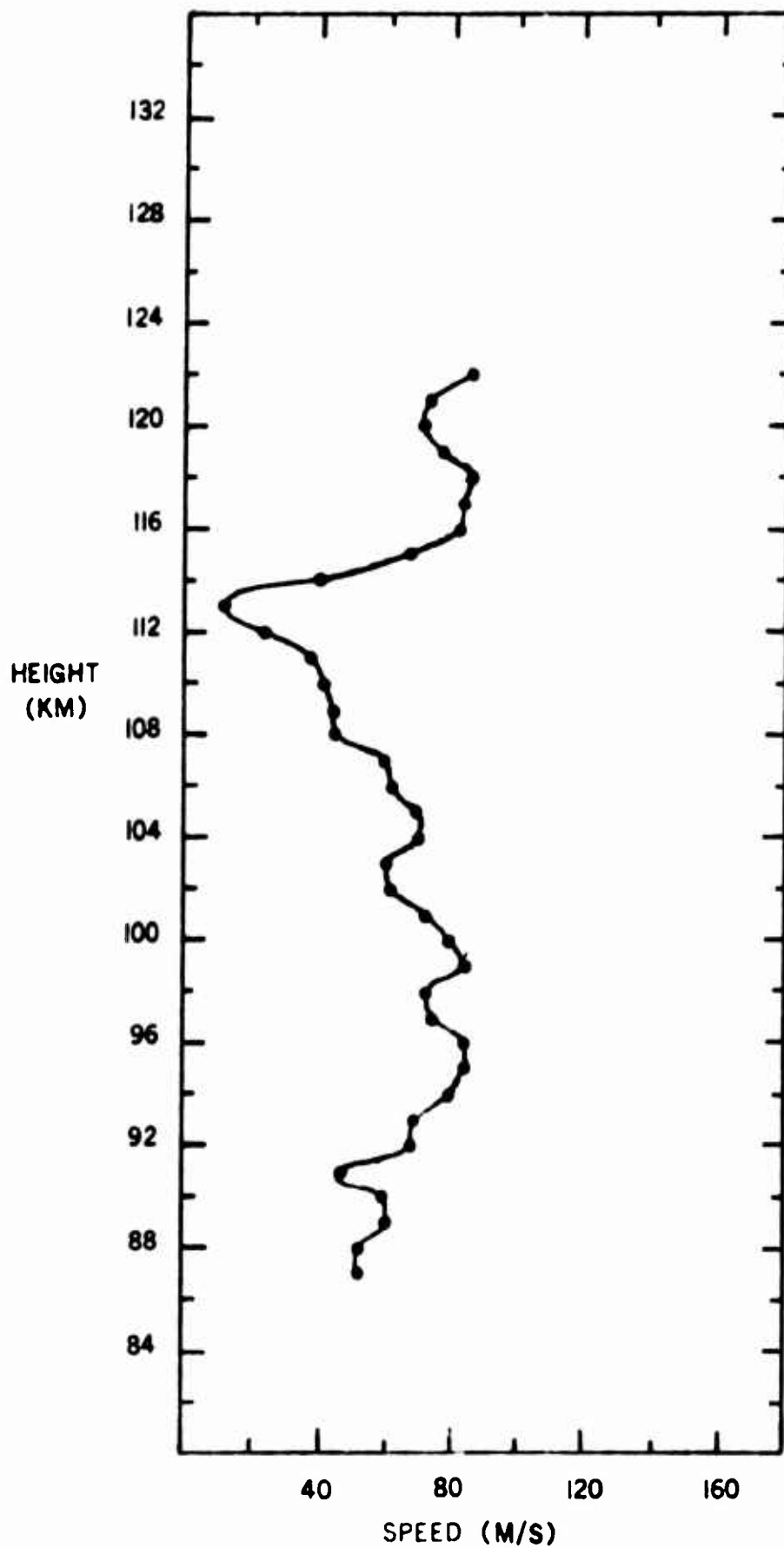
● UP TRAIL

15 JUNE 1966

03:05:01

▲ DOWN TRAIL

H.A.R.P. YUMA



WIND DIRECTION

TRAIL NO. Y5

MOLSON

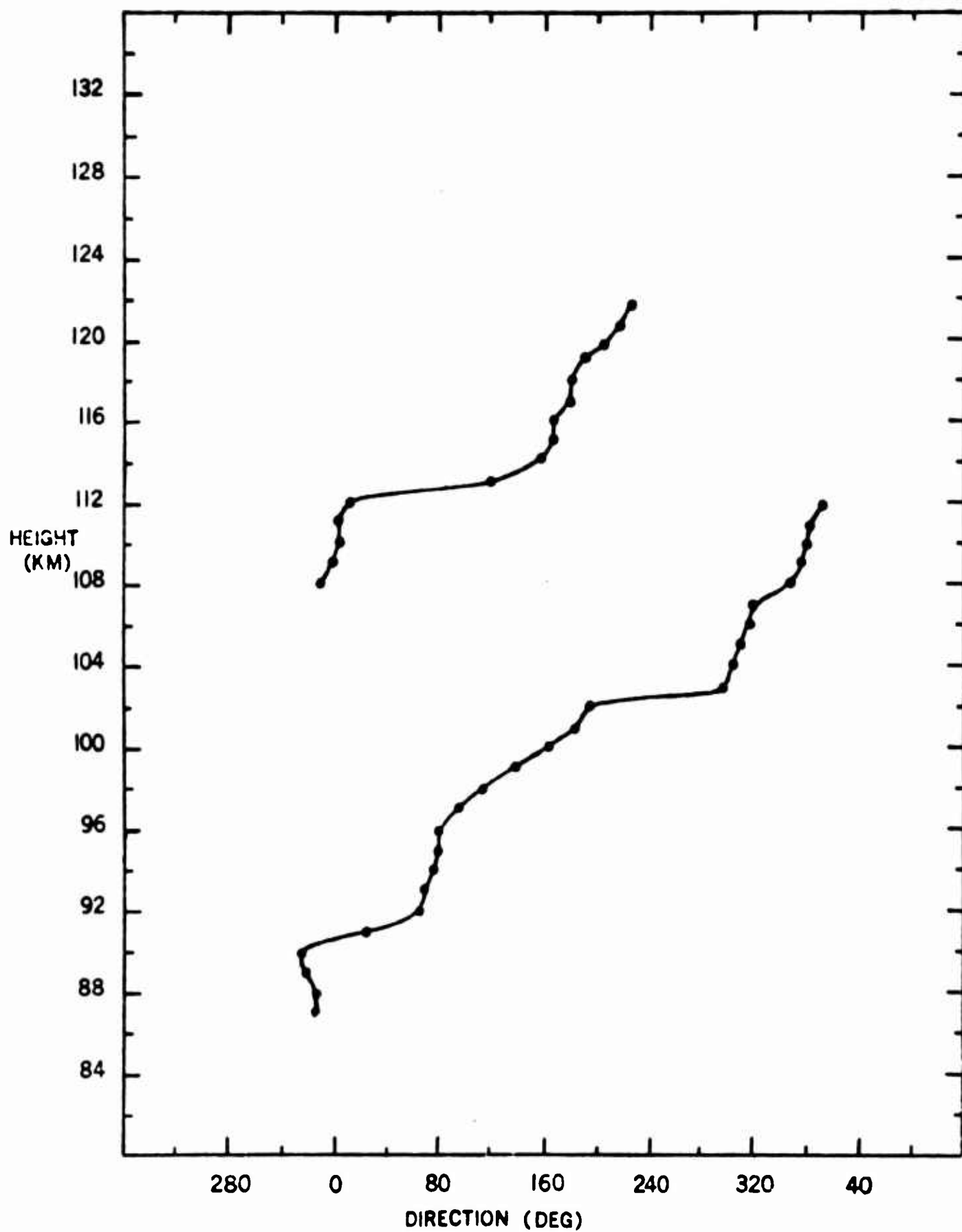
● UP TRAIL

15 JUNE 1966

03:05:01

▲ DOWN TRAIL

H.A.R.P. YUMA



UNCLASSIFIED

Security Classification

## DOCUMENT CONTROL DATA - R &amp; D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

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		2b. GROUP	
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4. DESCRIPTIVE NOTES (Type of report and inclusive dates)			
5. AUTHOR(S) (First name, middle initial, last name) Robert L. Fuller			
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11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY Commanding Officer U.S. Army Ballistic Research Laboratories Aberdeen Proving Ground, Md. 21005	
13. ABSTRACT On the night of 13 June 1966, two luminous trails were produced between 92km and 121km by the release of tri-methyl-aluminum from projectiles fired from a smoothbore sixteen-inch gun located at Yuma Proving Ground, Arizona (114.2°W, 32.8°N). An additional three trails between 85km and 121km were produced on the night of 14-15 June 1966. These trails were photographed by cameras located at Yuma and Gila Bend in Arizona and at Blythe, California, and have been analyzed to yield wind profiles. This report contains the tabulated wind data for all five trails together with plots versus altitude of wind components, wind speed, and wind heading.			

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